So where were you when you were asked to leave?

At the Hilton in Las Vegas. I hadn't won that much. About $500 or $1,000. But I was making big bets on multiple hands and then asking for insurance, which is a stupid bet normally, only when the deck was really hot with tens. So they knew and they asked me to leave. So I walked across the street to Caesar's Palace and sat down and won $2,000 in the next hour. It was easy to switch ____ each table.

Do they say it very politely?

No, they said it very harshly. But they were polite in the sense that they didn't do anything strong arm. They just walked up to me and said, "We want you to leave the casino after this hand." I said, "Why?" And they said, "You're operating illegally. You're counting. Want you to leave right now."

Is it really illegal?

To them it is. They define it as illegal.

But you're just shifting the odds a bit. What's illegal about that?

They have a right to say that it's not allowed in their casino if they can detect it. They can exclude anybody and they exclude anybody who's shifting the odds. It's not illegal. There's no illegal about it. It's not accepted by the casino, so they just tell you anything they want to tell you, but they tell you to get out. And then if they get on you, as they have with a lot of people who got in on it as business, then they get your picture out to all the casinos and you can't play anywhere. But I've never been in that category.

It was a hobby for you.

I don't know. I may have won $10,000 over time. Not that much.

And how about Cline Rock?

I don't know. He's probably similar; maybe more. He's played -- neither of us play that much anymore.

So was this back in the 70's?

Oh, yeah, probably mostly in the 70's. I still play when I go to Las Vegas. I just play because it's fun and I can break even and make more money. The last time I went there a few weeks ago I won $1,000 or so. Just enough to pay for my hotel bill. But it avoids you having to lose, you know.

Sure, yeah, and I bet it's the only thing you do play.

Yeah, I play that and Baccarat. Baccarat is a very fair game and I've got an accounting system of that, that can get it to be a little fairer. Never positive like Black Jack, but if you play a very fair game and you're willing to quit when you're ahead, you can do very well.

So you've never touched a slot machine.

I don't go for slot machines or anything else. I know I had a system for Roulette at one point, but that takes hardware and I never went back to rebuilt it properly. You can project the trajectory of the ball if you have the right computer equipment stripped on your body somewhere. And so I did that once and the computer equipment failed. It was very early in history. It was all transistor flip flops and it failed in the middle of the process and I couldn't make it work anymore in the heat of the casino. But it worked in the lab very well predicting the trajectory of the ball, but it's a very complicated thing to do, so I never really did it.

What does your wife say about this hobby?

Oh, everybody loves it. Because they get to go play Black Jack and if you play next to me, they can win too, because you can just bet like I do. So anybody betting at some -- all of the women that I married or have been involved with and have gone to Las Vegas with think it's great because they can play too and win. That helps. All you have to do is learn to play and then if I'm betting

properly and they bet the same thing, then they will do better on the average.

I've heard that you don't need much sleep.

I don't know that that's quite true today as much as then. I mean, yeah, maybe I only sleep six hours or so, but I try to get six hours -- somewhere in there -- five/six hours. I think that may have been from the fact that I had strange hours in the computer history and everything. But no, generally, I don't need an excessive amount. But I don't know. It's not a major factor in my ability to do things. At the moment, I spend a lot of time looking at life extension and nutrients and supplements that can help me keep active and keep my brain working. So I spend a lot of time thinking about that and working on it, and I'm probably one of the world's experts on that now.

Nutrients.

Yeah, _____ and drugs and other things that can help you -- I mean, prescription drugs that can help you maintain your youth basically; maintain your brain working properly.

Prescription drugs for maintaining your brain?

Well, one of the ones in that category is Depernal. Depernal is probably the most exciting drug known for extending life and in all of the animals it's been tested on, it extends life by 30-40% -- the life span. And the reason for that -- it's used for Parkinson's in people, and the reason why it's been official to Parkinson's is it helps keep your decline of dopamine from occurring in your brain. Dopamine declines throughout your life starting when you're about 25 throughout until you die. If you don't die of anything else, you'll die of the decline of dopamine by itself at about 110. So in that time frame it's gone down by 13% a decade. Every decade your dopamine declines and that determines your muscle fitness, muscle coordination, your sexual libido, and your feeling of well being. All of those things are sort of tied to your dopamine level, so you -- that declines all your life. Parkinson's victim, for some reason it changes the declines much more rapidly. The reason why it changes it _____

_____ or shock that occurs that makes the thing work differently. But however, the Depernol was developed for Parkinsons and it's very good if you hit it early. It can actualize stabilize it and protect against Parkinsons. Because what it does is it keeps the enzyme that's destroying the dopamine from -- it destroys that enzyme. And there's an enzyme that's created in you as you get older more and more that destroys the dopamine. It's not needed. It's a waste in your body.

Tape 2, Side A ends.
Tape 2, Side B begins.

As you get older, you start wondering whether there are any things out there that would help as you start not being as quick and as fast, your memory goes, and so on, and other things. And so you start looking at this and I started studying it like I do any type of subject. I started getting all the literature and going through the research reports. There's 100's and 1000's of research reports being published all the time on all these things and is ignored by the medical community, because until somebody brings out a drug that a drug company can sell at a profit, we're not going to do anything. The doctors will never look because there's no drug companies telling them about it. And no drug companies can sell these things in general because they're not -- most of them are available on the market anyway. They're not something you can get a patent on or an exclusive on, and aging is not considered to be a disease, so they can't do legitimate research or even prepare drugs for aging according to the FDA. FDA prohibits that.

For specifically aging?

Yeah, they specifically inhibit anything that isn't a disease, and since aging is not considered a disease, they're not allowed to create drugs for it. So they can't come out with a drug and prove to the FDA it's important for aging because it would be denied. They have to prove it's for something else like Parkinsons or Alzheimers, and they have, and there are drugs for those things that are useful. Some of them have not been approved in the U.S. and are just available overseas. Several of the ones I take. Some of the ones are available in the U.S. The majority of them are just nutrients that are on the market _____ and other things

like DMA(?) which is probably will change your mental capacity by immense amount as you get older and improve it.

Like what?

DMA which is dimenthol(?) which is _____. It's a liquid or a pill, one of the two, that you take a very moderate amount of, small amount of each day, and it goes across the brain barrier very smoothly and then becomes calline(?) and converts to (in the brain) and converts to provide the essential amino acid for your neuro-transfer activity of your brain, and without that, what happens as you get older, your diet doesn't adjust calline anymore and you can't get the calline in your food that you need. Somehow your liver and other things don't work as well to digest it and you don't get the amount you need in your brain, and one of things that's very clear and also is in other patients, and other people, is that they're very short on this and the brain just can't operate because it doesn't have enough of calline or sedacalline as the neuro-transmitter. And if you provide it more sedacalline by some one of the mechanisms, whether taking calline in huge amounts or taking DMA in smaller amounts, then you can avoid this problem and your brain works a lot better. In particular, you can notice it very effectively. You know, you take it and your concentration improves dramatically and you're able to concentrate on things. You're able to think about things and be more creative, lots of inventions and so on.

You've found this to be the case with you?

Yes, I find it very effective. And I found that, in fact, if I want to drive for a long distance, I find it important because I can concentrate on something boring like traffic. Otherwise I'll fall asleep, and so on. There's a lot of things like this that are known and are understood and are quite effective and quite safe that very few people talk about. Because the doctors don't really care or know or have any interest in trying to do anything about it. It's not part of their business. There's nobody whose business it is.

That's very interesting. How old are you now?

Well you're young.

Relatively, but on the other hand, there's a lot of things that would be effecting me a lot more than they are if I wasn't doing some of these things.

What do you mean?

The fact that I'm able to do the technical design and leadership of this project and go in and look at the design and protocol and so on, is probably due to the fact that I'm taking these things.

Sounds really interesting.

Cause most people -- what I found before this, you know, before I started doing this in the last three or four years, that the -- yeah, a manager tends to sit back and wait for interruption and not do anything. You know, it's very hard to get in a program and date work -- certainly program, but write and detail analysis, protocol analysis, and anything that's very complicated. The brain just sort of gives up. It doesn't want all that complication like it did as a kid, and so you just basically, you're not getting the ideas. You don't thing fast. It just doesn't work well enough. And so you just sort of get to using your knowledge and your background to manage and be an efficient manager and run your business. But you aren't contributing like you used to contribute.

To the body of knowledge.

Yeah, or to generate ideas or whatever. Whereas, with some supplements in terms of this, the DMA, prostitan(?), a few other things, the brain works like it used to work -- like it did when it was 20. And so you're able to contribute like you used to. It makes a big difference.

Just to play devil's advocate for a second. You don't really have a control.

Oh, I have a control. I knew what it was before this. I knew what

I was like. And I know, I mean, there's hundreds and hundreds and thousands of studies, so there's all sorts of controlled studies where they did double blind studies and they do that. And so all those are available and I've read hundreds of them. So I know what each one of these things do individually. Nobody has studied taking them all at once. Nobody has studied what it does if you take them to live much older if you're a human, because nobody's taken them for that long.

When did you start taking them?

Oh, two years ago, maybe. Various things at various times, but basically, some more recently, some further back. So all that becomes a very major factor in terms of how you feel and how your body works and how everything happens in your body, and it's -- but the studies are there to prove how each one works.

What does your doctor say about this?

Well, he thinks it's great. But my doctors are carefully chosen to be ones that know about it. Oh, very few doctors understand or care. My other doctor I've had for a long time who didn't know that much about it said, "Fine, do what you want, and I'll watch." He's open minded, but he didn't prescribe any of it. I have doctors that will prescribe it.

Did you find that you were having memory lapses?

Oh, you always find that as you get older. You keep finding you can't remember this or that and the other thing.

Oh, yeah, I know.

It gets worse and worse. But the worst thing is you can't -- I mean, if you sit down and say, okay, I used to be able to go in and solve a problem. You know, a complex technical problem with lots of things you have to keep in your mind. And that just got harder and harder to do with time, and now it's easier.

Or playing chess. All the things you have to be thinking.

Perhaps, yeah. Lots of different threads you have to keep tracks on. Chess might be a good thing -- I don't know -- to test it on.

Oh, I bet, yeah. That's why they peak so early.

Yeah, well, your brain actually -- your whole body peaks at 25 and then it goes downhill from thereon. And all these things, I mean, I can lend a list, twelve factors that are going wrong in your body as you get older, and they are programmed by your body to kill you off so that you'll get out of the food chain. And evolutionary wisdom would say that's the right thing to do. Get rid of them after they've had their kids. And so we know that that's happening. We know evolution planned it. We know that anything that kills you off after you're 50 is great. But not for us. But it was for the evolution. And so you can see the dopamine, the melatona(?) declines. All sorts of things that are going wrong with your body day by day, and you can fix them. Melatona you can take. Dopamine you can fix so that it doesn't do it. Each one you can attack. Melatona -- you say you don't sleep so well. Older people tend to sleep less and less and it's because of a lack of melatona. Melatona is a hormone you can buy on the market, no prescription. So you can just buy it and you can supplement it. It will fix the jet lag instantly.

What's it called?

Melatonin is how it's sold. It's a synthetic hormone, melatona, and that's what your body generates all day and then it's used at night to put you to sleep. It's what gets out of sync when you have jet lag. When you fly to another place, as your melatona is occurring at noon and you're trying to go -- and it's being dumped in your body and it makes you go to sleep, but it's not happening at night. The light cycle tends to get back in sync eventually, because you see light all day and it's generated during the night.

Yeah, I've read about the light factor.

But if you take synthetic melatonin when you get on the plane at midnight in the other place and you fall asleep, and then you're in sync, and everything works fine. It just puts it back in sync synthetically. You go fly to Europe and be useful the same day.

No, not that much. I just was there a few weeks ago. It looked beautiful. But the melatona is also important for your body not to get -- not to use too little sleep. In other words, it's actually not a question of need. Your body needs sleep all through your life, but you don't get it because you don't fall asleep because you don't have the melatona, and then it doesn't get repaired, and the body gets hurt more and more by not getting occurred each night. So if you don't get four to six hours of sleep, then you're basically hurting yourself substantially.

Four to six?

Well, yeah, something like that. I'd say six probably. But some of the doctors would say four. Somewhere in that range. Somewhere in there your body starts not getting rejuvenated. You're not used to it. And they've done tests, and basically, cutting people down by two hours and the effect is their T-cell(?) counts half of what it ought to be.

Right. Which is why we're more vulnerable to getting sick.

It rebuilds every night. So if you take the melatona, that fixes that. You take it each night, take the right amount. You have to figure in how much is it paying for you. We've worked it out. I have a group that meets every month that tries to figure all this stuff out. So we have a lot of ongoing research in the group as well as reading articles. But it's also _____ itself. It's not why you can't.

Well it's very interesting.

I'll give you --

[Tape is turned off and back on again.]

Who was working in the network control center, and you said at 1:00 or 2:00 in the morning, they'd get something from you saying, "I need to put together a presentation on such and such about the network," so then they --

one authorized, but they never went in business. But we were the first data carrier, basically, for packets.

So you went from Arpa to Telenet?

Yeah.

Tell me about your recruitment.

How did I get recruited?

To Telenet. What happened? Did Levy recruit you? Is that what happened?

I had gone out and said that we need a commercial service to take this over in Arpa. I went to AT&T. I told you about that. And they turned it down. I then went to the Burney Strausberg(?) at the Commission out of VC(?), and he was one of the commissioners then or the head one. I forget which. And Burney said that there would be no problem to create and get somebody authorized. He'd love to have a new carrier for packet technology. It was an ideal thing to do, and MCI had been trying to get a new license for that plan, but figured that -- he thought it would be even better to go in with a new service altogether, and so he was perfectly willing to authorize somebody. He thought that was a good way to go, and they could even take over what Arpa was doing or anything like that that they chose. But then they had the elections first. They couldn't get the elections based on the other one. So we basically -- I was trying to push that approach of the Arpanet being taken over. So I went to BBN and I said, "Why don't you apply to be a carrier? Why don't you create this?" And they thought about it and they said, "That's a good idea." They hired Stu and Phil to work on it, and Stu and Phil worked on the legal and the marketing issues for a few months in '72 and decided that it was a good idea. Convinced BBN management. BBN decided to go ahead and do it on the condition they could get me to run it, and Stu approached me to run it. Barry will tell you -- which is true -- that he then encouraged me a lot as well, because he had also been recruited in the same period to be involved. If I would go, he would, and so on. So that was that. But there was a lot of -- but it was really the fact that I wanted to get it commercial and that was a good way

to make it happen. So I said, "Fine, as soon as they find a replacement at Arpa." And I had presumed at that time we might actually find a way to take over the Arpa business. But as things evolved a little bit, it became clear there would be a conflict of interest if I went there and did it, and we didn't need it, which was not a big deal.

What do you mean, "Take over the Arpanet"?

Well Arpa had this whole network and Arpa didn't want to keep on running it. So if we build a network, we could take over Arpa's current activity which was a possibility. But it turned out that was not attractive to do, wasn't important to do, and it was a conflict of interest to try and do. So I didn't ever bother with that part of my idea. But that's one of the reasons that I had been pushing this whole thing all that time. So I agreed to go and six months later I finally went, because I had to find a replacement and I couldn't find one, and I finally got Lic to come back, and Lic -- it was bad for him and the community that he did, in some ways, because he really couldn't -- didn't do a very good job at that point and time.

Was he older?

He was older and he didn't really know how to handle it at that point and I don't think that Arpa management treated him with the same -- was compatible with his thinking as much, so he didn't get -- the money shrunk a lot under him. He didn't have the same support internally at Arpa and he couldn't get the same things done, and so he finally got Colonel -- somebody to take over and then he did it for a while and then it grew back, and then Bob took over and it grew a lot more.

Kahn?

Yeah.

So did Kahn -- at the time that you --

He was still there, but he wasn't ready to take over the office really at that time. Maybe I should have given it to him. Maybe

that would have been better, but Bob matured a lot in the next couple of years and then he took over.

So he was young too?

Yeah. And Bob, when he first took over, had immense troubles with the Arpa _____. Couldn't get anything out of him. It was blown up much too much in his mind for that guy. And so he wouldn't build any of the structure for the director that the director wanted. So when you talked to him, he'd talk about these concepts that were sort of isolated clouds. He didn't need all the structure and build the logic because he knew it all, and he didn't say that he needed to say it, because it was obvious to anybody who had an intelligence over 200. So he didn't say it and the director just couldn't communicate with him. It was almost impossible. So then the new director came and then things took off. Could have been the director could understand him.

And who were these two directors?

I don't know the directors.

I can find out. Kahn obviously would know.

Yeah, and so then they took off and Bob built the office up tremendously. I mean, from the 15 million I had, he went up to 200 million or so.

When you say "the office," you mean IPTO?

The IPT budget, yeah. The whole history of that budget and what it's done for the country is really important because it's been a critical part of the country's development in computing. If we didn't have that original work elected, we wouldn't have an industry because we would not have computer science people. You wouldn't have the people because they wouldn't have gone to school. There wouldn't have been the money at MIT and Carnegie and so on to develop the engineers. And so the criticalness of the office is far more than people even than their programs. Arpanet is probably the most successful program. But the people generated by the Arpa budget and Arpa activities over the years has been the majority of

the people in computer science, even though they may not even know it. Because almost all the computer science departments were funded primarily by Arpa and Arpa research. So it's been a major impact on the U.S. and getting it ahead of other countries in this area -- or equal to anyway, at least. Ahead in a lot of ways.

That's an interesting take on it, because one doesn't usually think of that unless you've been there. Now is that where the high performance computing comes out of?

Well that's the new name for one of their programs, yeah. They have evolved into where they think they can support their programs in high performance computing communications and so on. But that's the job of the people who were in the office at any moment in time is to keep on choosing the programs that are leading edge that they can sell that are congressionally supportable that have a defense need that they can identify which is almost anything, and that are a step beyond what industry is going to be on its own. It's going to try and push things a little further. And it's always hard to keep it there because they're pretty sure _____ going to do it and that it's not worth funding anymore. So you have to keep moving a little bit ahead and it's a continual job of finding great people to challenge and to keep their upper hand in. It's not always been done perfectly. Some years it's been much better than others. The better you do it, the more money you get.

Now did you leave Telenet after GTE bought it?

Yeah, we grew Telenet from '73 to '79 and then GTE bought it. We'd already gone public in '78 or so. Still didn't have the size to attract customers like GM. GM had tried it. Thought it was great, but wouldn't buy it unless we were bigger. Just wasn't willing to bet their company on this little company, because if you start betting your company if you depend on it, and we go out of service for a few months, you can't exist. So we realized we couldn't really be in business as a tiny carrier very easily and it was best to make a deal with GTE if they wanted to and they did. So we did. We made a deal with them where we would sell it out to them. They seemed very cooperative. The FCC insisted it be kept as a separate company. So there was an agreement with the FCC. Since we were both carriers, the FCC had jurisdiction of it, and they said it had

to stay as a separate company, and actually they intended to keep me running it, but after a year, GTE concluded -- I had a three year contract. I had to stay for three years. And after a year, they concluded that they had all these other development areas opening -- ATM switches, data -- digital PBX's and everything else that they wanted me to direct, and they wanted to put somebody else in to run the network and so they did, and they put me in charge of a new subsidiary basically doing all this -- building ATM switches, basically. And so I said, "Fine, whatever you want me to do," and I did it. But I really hated their management structure and their style. I had new bosses every six, three months or so. They kept on trying to find a structure that would work. Their management was to hire somebody who didn't know anything about the area and had to manage it, and it was a disaster, because they had 15 staff to do it then. I mean, just structurally and managerially, the monopoly background just didn't work. And so I found it really not the place I wanted to be. So even though I got this big program I'm going to do -- the first ATM switches around -- one of the first ones. It was one being built at AT&T, as well, in the research labs and we were building one. It was actually development. We were going to have a product. And it wasn't called ATM then. But it was fast packet, _____ packets, and so on. We were starting to work on the standards. Then I did that. Got all that going and got actually data PBX's out on the market. Not _____; some other ones. But after my three years was up, to the day, I took another job because it was really not where I wanted to be, and DHL came along and offered me a job as the head of DHL, as well as to build their network stuff up, so that they could go in like _____ in that business. And I had believed at that time that there was room for fax. It would be a very good way of exercising packet technology and would be big business for packet technology and would be a very good mechanism for courier and need a courier to deliver it and pick it up in other to have the widespread accessibility because it was expensive. So I thought it was a good idea, and then we got together and I managed DHL out of its being an embryonic start-up almost into a real company for basically a year, and put in all the financial systems, personnel systems, and everything else that by then I had learned how to do, that were necessary because it was a cash draw operation up to then with the entrepreneurs. And got the domestic airline going so there could be a domestic courier

business in the whole airline, and got the _____ express going and got that operating. But my whole agreement was in that I have stock in that express, not in DHL, and so then my transition in _ _____ express to really worry about its stuff and build a fact car, and we did and that worked great, except the customers quit as soon as they started. So we got lost. There was no _____ on that express. We sort of took all our technology and went into business selling fax equipment and we started making a profit from that. So we were fine for many years, and then I went out and got a contract to do ATM switching with FDIC(?) and build their switch, and that was very attractive and built their whole switch for them, and then why don't we take our people and go build our own switch. Tried to find money for that. Well, DHL didn't have any; neither did Cannon(?), who was also an investor; nor did they want to get in that business, and so we found IMP to do it and then bought that piece.

Which is what this is. So you made the switch over to -- it's sort of a gradual switch from scientist going over to the business side.

Well I'm still sort of a mixed miller. Like I'm doing all the design on the switch too.

You are?

Yeah, the actual integrated circuits that we're doing, I'm going in and looking and doing the design. I'm being also control. I'm working with ATM forum to design the whole control scheme that the whole country and world is using. Because nobody hardly understands the technology well enough anymore and not many people understand it like I do. The queuing and the flow control and the whole thing. So in order to take all of that and apply it to our product, it's best if I use all my knowledge to make that happen. In terms of running the company, I believe it's valuable to be in control so I can make sure the right things happen, but the way we structured this is probably good in a lot of ways. I'm not trying to run the marketing and rest _____, rest of IMP and I'm just running all _____ right now, I'm sure so that we build the product want and get it out. Cause I don't want to really run everything. That's really outside of where I want to spend my time. This is really worked out to be best to being directly

responsible for the whole activity that's running the -- building the product and applying the technology.

Well how have you enjoyed managing?

Well, managing is very important so that you can get your ideas affected. I enjoy it. I don't believe that I want to spend all my time doing that. I want to do designing. I want to apply those ideas through lots of other people and so I've got to have a mix. Sort of how I can be technically on top of it and make sure it happens, just like I do with Arpanet. And I designed it and I managed the whole program _____ the office.

Yeah, it wouldn't have happened without you. That sounds can of trite, but also true.

Well there's also a lot of differences some how in the way I think economically. These graphs and so on, nobody else does that. I mean the whole economic trend analysis that I tend to do or think in is just not common. Very few people have the math background I have. So here, I'm the only one who does Q-intherium(?) and can manage the probabilities of the traffic in their mind very well, and so, engineers tend to be pretty strict in the way they do things. I mean, they take the worst case and they design around that and that results in a system that's much too expensive and doesn't work.

What do you mean, "they take the worst case and design it"?

Well, if you have a problemistic travel flow or collection of things, and so they say, "Okay, well all of this could happen at once, so I'm going to have to build it so it has the capacity for the worst case." Well if you do that with something that's supposed to average and have statistical averaging and buffering, then you'll wind up with a system that's 100 times too expensive or it's designed wrong. So you have to really apply probability theory and statistical theory throughout the design, in order to say, "Okay, this is within where we want to design to in this rate and whatever this is at outside of it," and they keep that in mind with all of the design, and probably that's one of the most difficult things to find people who are good at it. In the

engineering world, I have found very few people you can hire along those lines.

Frank Hart, on the other hand -- Kahn has told me stories about real run-ins he had with Hart when they were building the IMP. Saying to him, "Well this could go wrong," and "this could go wrong," and especially this reassembly lock-up, when they'd all be coming in too fast. You know, incomplete and run out of memory, so that the rest wouldn't get there. He said that Hart would say, "Don't even worry. We won't even think about that. Let's just build it and if it happens, it happens." And then Kahn tells the story about them going out to UCLA with Walden and making it happen.

But all the things are -- have to be mixed appropriately. I do the same thing as Frank some of the days. I say, "Don't worry about it. We'll deal with that one later." Because I have in the back of my mind a way to deal with it later. A way we can handle it. But if I know it's going to change the heart, if I'm gonna have to read it on the chips, I can't do that. It's going to take too long. It's like if I can fix it with software later on, I'll -- you know, I got too many problems this week, so I'll deal with that one later maybe. But you also have to analyze those problems and try and find a solution to it. And if you have a tentative solution and one that will work that you can manage the problem, like _____ lock-up so that it -- so yeah, you can get congestion and everything can happen at once, but you can make sure you have one buffer available all the time to do something. Then you make sure it never locks you up totally. So you look for those solutions.

Well now but people have said that Hart's attitude being what it was is what enabled this thing to be built so quickly.

It certainly helped. And in fact, that's why I have to tell you that compromise between what Frank did and what Bob did here. They did a lot analytical looking at what their problems are and try and understand and fix those, but I also look at what I think will work in 99% of the cases and let's go build it. But simultaneously trying to make sure that we don't make a harmful mistake; you know, one that I can't fix later with software.

And that didn't happen.

No, he didn't have any hardware mistakes because he was using a commercial machine. He didn't have any hardware developed really. He had an interface developed, but -- so they always could fix it with software. No, we don't have the situation with ATM anymore. Almost all of it is in hardware. Have some background management tests in software, but all of the basic functionality of ATM in hardware. It's not only in hardware. It's in chips. It's integrated. It's into it. It's into _____ to take six months to change.

So what would you say Severo Ornstein's major contribution was?

Have you found him?

Yeah, I'm going to go see him tomorrow. He's quite assertively not on any kind of network, so we exchange postcards.

Up in the hills somewhere.

Right. Wasn't Taylor telling me that you moved?

I live on the hill too. But Shapiro lives on the other side of the hill somewhere.

So you've all ended up within --

Small distance, right. I see him in the restaurant on the top of the hill. Anyway, Shapiro has clearly contributed a tremendous amount to the actual design of the equipment. I mean, he was very, very good at doing the -- making the technology work with the hardware pieces. The particular contributions, I have a hard time remembering. I think you'd have to go back and talk to him. But anytime you wanted to get anything -- understand how the hardware worked or this piece or that piece, you know, figure how it was, he could design it, build it, fix it, and tell you what was going on with it better than most people. But he was just very capable in terms of doing it. And worked with Frank very well, and so he was able to work with Frank and get it all done, and if Frank said, "do it," he did it.

I've heard them described as the perfect combination.

Right, something then happened and he went and hid in the mountains.

Did he go to Parke after?

Probably, I've forgotten exactly.

I guess Parke, for a while, was recruiting so much from DDM and DDM wrote a letter to Parke and asked them to please stop.

Well Parke was recruiting so much from all the Arpa sites that I tried to calm them down a little bit even at one point, because it was actually substantially hurting the research programs at all of our locations. Because they were taking all the top people and giving them bigger salaries and letting them do nothing. I didn't see that it was benefitting the country to do that. It certainly was hurting a lot of the major programs and Parke was turning out nothing. As it turned out, it never did anything with the Arcs(?) really, because the Arcs wouldn't look at what it did. It did do a lot of good things. But people were allowed to not do that much and be free with their ability to just sit around and do things, so that it was a different environment. One that was good to have around and I contracted with them to get them _____, but one that I wish they hadn't stolen so many of the people. It was fun for the people.

Sure, yeah.

And then, I guess, Bob came into severe arguments with the people and went and did the Deck book. So he did the same thing for Deck.

You mean the circuit --

The duct(?) research.

Are you still in touch with Taylor?

Yeah, from time to time. Not too often.

Do you consider these people your friends?

Oh, yeah. I think they're all my friends. Severo, I haven't seen in so long. I saw him once in the last ten years, maybe, on the hill just by accident in the restaurant. I haven't had a chance to communicate with him, but I'm _____. Nor do I have much reason to try and look them all up all the time. I don't go see Bob very often. But Bob and I keep in touch more often and talk from time to time. They're all friends. They're not people who I associate with on a daily basis. There's people like Cline Rock I keep very close to, _____.

Yeah, I've heard he's your blackjack buddy.

Well, yeah, one of them.

Someone was telling me that you guys have actually been asked to leave because of counting cards.

Yeah, not together, but individually.

I guess casinos can do what they want.

Oh, yeah, and they typically ask the counters to leave all the time. We actually did better than typical because we were generally not noticed. We were pretty good at it and didn't do it consistently as a business, so we didn't get hassled too much. The day I got asked to leave, I was just being much too blatant. I knew that I was betting on things that I wouldn't possibly know how to do if I wasn't counting, and if a dealer wanted to, he'd know something was going on. They did, and they had the casino people from the ceiling counted with me until they knew that I was counting, and then they asked me to leave. But they didn't record my name or picture or anything, so I could walk back the next month.

I've only read about that. Like Thorpe brags about that.

Yeah, Thorpe's system was extremely poor.

Is it?

He published his book back 30 years ago. I don't know when. I had been looking at it and I had been working on the computer and I said this is not very good. So I worked on improving it a lot. I'd already been working on it some, but I worked a lot on improving it. I got to a system which was vastly easier to count than Thorpe's. I could count through eight decks. You know, whatever I chose to without any trouble -- six decks. And Len had learned Thorpe's system and we got together and I taught him mine eventually, because Thorpe's system was just impossible. One day, we went to a casino and he counted with Thorpe's system, which was you had to count the tens and you had to count the others and then you divided the two all the time. The division killed you.

Cause you had to do it so fast.

And you had to do two counts in your head. And I counted one count which was an up/down count. It's called hi/lo. It's the system now and everybody uses it. It's the only system used probably today. And it's never been published. It's all by osmosis, but everybody does it in their system. Amazing.

Right. You've always got a balance in your head as you go through the deck.

Right, but what I had proved 20 years ago -- I did most of this when I was at Lincoln Labs, basically, in the early 60's. I proved that there was no problem with determining what the best system was. The best system was the hi/lo system. I mean, you could, in fact, go through and you could determine that there was no better way to count unless you had tremendously more counters in your brain. But that was the best way -- approach to counting cards. So anybody who looked at it seriously would find the same answer. And you could get a 3-5% advantage over the casino by doing that. So I developed that. I'm probably the only one that ever computing the variance and the second order published probability statistics. I took a long time to figure that out. I never published and grimly never will. But so that I know what the time and I know the probability that I'll make money or not. In other words, you know you will over time, but you don't know whether you will all in one day. It turns out it takes about 24 hours of playing before you can be relatively assured of making money.

In fact, everybody in Arpa started using it including the _____ _____, who ran Arpa. He was the director of Arpa at the time. And everybody started using E-mail and it became a way of running our remote offices and doing everything over actually a very few years, because I was only at Arpa for six years and the Arpanet was in '69. I left in '73. By that time, everybody was using it for everything. And the volume of mail was so horrendous that it was hard for one to get through it each day. That's true today for people. But it was true back then. And we developed this whole on line publishing system through SRI that became very, very active in a later period, where all of the research from '69 through '73 was being done.

All of what research?

Packet research, in general. We started the work Y-packet radio. And then from that I published the slotted _____, which was the work that showed how you could use -- slot the time periods and get twice the performance of a random time period. And then reservation techniques for reserving satellite band _____ and so on, and those -- I published several papers like that. People were publishing all sorts of things. Bob Metcalf had _____ and went into Ethenet(?). I mean, it all came out of that same group of work that was going on at that time. Very, very active. All published on line _____. We didn't bother with publications. We published it on line. It got a number and then it was available to everybody. And the effect of that was a very, very tight group growing very fast. We've seen that again in recent times with ATM now. Very, very active development of ATM form by E-mail and so on. Everything is happening overnight.

Where were you in things like for Matt's last theory, just in terms of how quickly information is spread?

Well yeah, I mean, things have been spreading faster and faster, but to tighten up the research circle to where people are inventing faster and faster, cause the transfer _____ so fast has sort of occurred in bursts, at least in this field. From '75 to now to '90 something, not as much happened. I mean, it was almost a flat period. Everything stayed _____, but nothing changed.

Really, why?

Well it was basically that people were now refining packet switching for commercial X-25 use. The standards were there for X-25. They couldn't get above 56 kilabits too easily with the technology that was around. People were trying to get that into the networks, and so there's lot of time of just expanding the infrastructure so that it was all there in place. Whereas, the speeds have been growing since -- well, you know, B-graphs that I have if you want of how that's changed over time.

Now just to backtrack for a minute. When you got back the answer from IBM and CDC and they said, "No, thanks," what was your reaction? Did you think, oh, these guys are all wet?

Oh, yeah. We knew they were all wet. We just laughed. It was the funniest thing around because we saw them as totally being entrenched in their own technology. And I had talked to them and I knew what they were going to say. They basically weren't saying, "No, thanks." They were saying, "You idiot, you stupid idiot," is what they were saying. They were saying nobody could do this. This is hopeless. The _____ speech is that DCA, the Domestic Communications Agency, and they threw rotten apples at me. I mean, it was so bad. I mean, they just got up and cheered and screamed and yelled and made really nasty comments because they believed that this was impossible. The ques would over --

When was this?

This was when I was proposing it in '67-'68. The people were just absolutely -- in the communications field -- were totally obnoxious and totally incapable of believing it would ever work. They thought it was hopeless. It would never work. That it was the stupidest thing anybody had ever tried and they were ready to kill it, if they had a way to do it whatsoever. Of course, I had the support to make sure that that didn't happen. But the reason for that was so clear to me. The biggest lesson in my life was that. That people are so resistent to change because they've got all these things that they believe are facts in their mind and they build a whole foundation of knowledge on it. Well some of those things if they're not facts, if they're really just conclusions

from some other set of assumptions and aren't true really, then this whole thing topples and they can't -- their whole mind has to be restructured. Well they're not willing to do that. It's too much work. So as soon as somebody challenges one of those things that are down at the bottom, like the whole basis of communication being packets rather than circuits, then they just couldn't accept it. It was too big a change in their mind. What they finally did -- almost all of them -- just said, "Okay," after I built the Arpanet and it worked and it was successful and everybody was having tremendous results with it and the economics were tremendous, then they concluded, "Okay, it's okay for data and voice is going to stay the way it is." And so they segregate it in their minds into basically voice video, real time, and this data stuff. Maybe the data stuff can have these properties. Maybe it can work this way. And they had to conclude at that point that -- before I started telling them -- they had concluded it wasn't going to be economic. I mean, I proved it. I wrote article after article showing the economics and how the economics worked and what it was going to be like, and how that was going to affect things, because I was the one who did all of the design work on the network and the topology layout outside of what NAC did for me, Network Analysis Corporation. A lot of design. You know, they had a big simulation program.

Was that Howard Frank?

Howard Frank, yeah. They did all of the detailed simulations as it got more complicated. But I did the initial designs and then got Howard to do the detail stuff as we needed it. And did all of the analysis and the economics to figure out how this was really going to work and what the effects of it were and how it was going to work in the system. And I spent a lot of time on that and I have a lot of papers, others things that were along those lines. And the communications people just couldn't believe even then that it was all going to be economical or anything else. I mean, it was reasonable we'd say. The peak to average ratio of data is 15 to 1. In other words, the peak burst rate is 15 times the average rate for time sharing basically. And given that, if you design a -- if you have a circuit, you're going to get 1/15th utilization. And if you have packets, you can get 90% or 95, depending on the overhead, utilization, and so clearly that's more attractive. And you can

get 15 times the economics and that's what happened in practice. We started Telenet. One of the reasons I started Telenet was to prove the whole thing was commercially viable. Second, I thought it would be good business. But even just to prove it to the world was important at that point and time. Because there was nobody who was willing to accept it outside of the fact that the research experiment was okay in the government and they paid for it. You know, it was sort of like Internet today. You wouldn't know if it was economic or not if you didn't have some external economics that were _____. Now the Internet is being sold commercially and you can, in fact, pay your own way. But nobody's quite sure they're paying their own way or not. They don't know what they're doing. But in reality, until I proved it then, we set our prices and they were about a 15th of what the dial-up service was at that point and time. We got the economics we looked for. But we had to develop the host protocol like the X-25 to have something standard, so that was a big job.

Tell me about your dealings with AT&T.

Well there's two major interactions with AT&T. One was near the start of the Arpanet and Bob reminded me of this a while ago.

Bob Kahn?

Taylor. And we -- and I don't remember the details right this second. Ask him to remind you of that. But in any case -- well, maybe not. Maybe it's the same one he remembers. Anyway, after we had developed the network, I went to AT&T, and this was around '73, and we said, "_____ with this experiment at Arpa. We have the experiment. We've proven it works." And we had concluded internally the best thing to do was turn it over commercially and let it run as a commercial network and just buy service. We'd be better off. We didn't need to do the experiments anymore. And so we asked AT&T if they'd like to take over the network and they could have -- they could be paid the same amount they were already getting for the telephone lines, plus for the service they could buy the machines from us or, you know, whatever they chose, we could make a deal of some kind, and they could have all these sites and all our service and we pay the bill, and then they could add other business. The best deal in mankind. I mean, it was just

giving them a new business with a head start. Whether we should have done that or not in retrospect is unclear because competition was just about to begin in the communication industry and that was almost a monopoly giveaway. But it was still a monopoly and we thought that was a reasonable thing to ask. Anyway, we went to them and they said, "Okay, we'll think about it, and they went back to the labs and they formed a huge committee, and actually, Bell Labs and AT&T, and they got together a group of major senior people, and thought about it quite a while and they said, "No, it's incompatible with our network. It's totally incompatible with __ _____ network. We couldn't possibly consider it. And so they didn't, and they didn't consider it for a good number of years with no competition from AT&T for Telenet or anything else for a number of years. They finally concluded after Telenet and Timenet and everybody were very successful that they had to do something about packet switching and they started their research program to do it, and they tried that, and then they told the researchers -- I talked to the people they hired. They hired outside people under an AT&T manager. So they hired the people from MIT and so on, and they said, "Okay, build a network and you've got a year to build it." So they tried. They failed. They couldn't get it done in a year. So then they fired those people and got new ones and they tried again, and they did that three times. Each trying to do it in a year, and didn't succeed, and they finally went and they bought some from somebody else and put in a network eventually. But I mean, it was much, much later. It was way past any point and time when they should have done anything. And they still aren't a very strong figure in data communications, you know, network service. It's hurt them tremendously over the years. They could have been the foremost factor in it, but they chose to operate the way they did, and the way they did was one, they concluded it was incompatible with circuit switching. That it wouldn't fit in their environment. Of course, that was nonsense. It does fit in and, of course, ATM will replace everything. It will fit in totally. And then, they couldn't get it going commercially because they believed they had to put in under the LI managers. The LI managers did not handle circuits and couldn't figure out how to manage the people. So it wasn't the people's fault. It was just that they -- I talked to the people. They were being directed this way and this way and told to change every week, because these people just didn't understand the problem. They put them under people who had this

other focus in their mind and didn't believe in it. Couldn't deal with it.

They were telephone guys through and through.

So they just couldn't deal with it very well and it was a real problem. That was the first example of the not being willing to change is exemplified by DCA's response and their response and everybody's response through that period was basically they really wanted to make packet switching not happen because they hated it. It was something that was going to change their mind and they didn't like anybody to change their mind. And then, when I went out to get X-25 standardized from Telenet, because I believed we had to develop a standard interface, so Barry and I went in and looked at it and we decided that the right design was a virtual circuit type approach, because we had virtual circuits on top of it, anyway, through the network, and we needed something that the terminal controllers like the TIP could work and run, and so they'd have to generate their own VC's, so we'd have to standardize the VC portion in order for the chip to work. So you have this terminal controller which is going to be an essential part of any commercial service to offer terminal services. And the terminal has to generate a VC. So if we leave that all up to the host, which was the purest point of view -- leave the VC totally up to TCB level and you should never look at it -- then we couldn't standardize it, and we had to standardize it if we were going to get the terminal part to work. So we took the virtual circuit approach of doing it with virtual circuits because now communications cost was -- the really dial in factor, computing was really much cheaper than it was to begin with. You know why cross over occurred.

No, I don't have any concept.

Well historically [steps away from tape recorder] there's a whole -- this is probably the most famous paper I wrote on the economics of packet switching. Why packet switching was economic, and it showed what occurred where the cost of communications was coming down rapidly -- I mean, slowly, and the cost of computing was coming down rapidly and I crossed over, if you looked at _____. And that cross over occurred in 1961. It's called the '61 crossover, and as a result, it's probably been reprinted over and

over back then. I've updated it more recently to include -- we [comes back to the tape recorder] don't have the document we're looking for which was one that has a bunch of Arpa stuff in it -- history stuff. Because I had an Arpa's history speech a while ago and it was --

Oh, yeah, that was the one at Sun?

But this is just -- this is showing how the speed of the Arpanet and Telenet and so on was all 56 kilabits for many, many years, and then finally we started growing on the Internet and on commercially. So now we're up to 622 or so and we'll get up to _ ___ gigabits after a while. But that's what happened. All of this time nothing happened really in that packet -- for circuit switching -- you know, finally got caught up with _____. That's about it. Generally, just general background and dates, but this is the crossover. This is the cost of packet switching computing. This the cost of packet switching communication. Now to design the packet switch, you had to use a certain amount of computing to do it, so this is the cost of that amount of computing to do packet switching. And this is the cost per kilasecond which is cost per bit move, basically. The cost of actually at 64,000 bytes. So this line, which it's varied around a little bit, but it's basically been pretty flat for a time. I developed it back here and published it in '74, and I find it's still correct today. That line is virtually -- it's stayed that way. It's basically the cost curve of how communications against this line have stayed that way to them and the curve -- I did a paper back in early -- when I was in the government -- '67 that showed what the cost of computing was, and it was 1.56 per year decrease in the cost of computing. I looked at all the commercial machines and everything on the market and what they cost per operation wise and I showed the government -- it was basically a government lease versus buy document I showed you. They said they should write it off in three years cause it wasn't going to be worth anything longer than that. But in any case, that same number has come up over and over, and recently, I've seen it as -- in a recent conference I was at -- ATM conference -- it was presented as Grove -- the guy who's running Intel --

Andy Groove.

Anyway, his rule or something. But there's lots of people. But it's the same factor. We all found the same factor. It's 1.56. It's the same number we get every year. It's the speed of semi-conductor improvement basically. So everybody's called it somebody's law. This law. That law. Intel's law or whose law. But in any case, it just keeps on being the same factor. That's that and this is this and this. The cost of the packet switching that was very cheap compared to this. We've put a lot more stuff in it, so it actually is not -- four _____ cheaper now. It's only about a factor of three or four because we've got so many more things in it that we can do now with it. But what was happening all this time is after '69 when we did the first Arpanet, it kept getting cheaper on the communication. The cost of the computers were very expensive and then we had very little memory and very expensive computers. It got much cheaper, so by '75 when I did the X-25 standard, I said, "Look, computers are that much cheaper. We can in fact afford to put the VC number in their path and keep the path information on the switches and get all that out of the header, so we don't have to spend so much money on the communications for the header." So using datagrams became less attractive. Well, I switched in '75 commercially and everybody in the commercial industry has followed that and stayed that way including right on through the ATM. And everybody in the government followed Bob Kahn and Vint Cerf who couldn't change their minds and decided datagrams were still the best and continued working with datagrams.

Vint Cerf -- he still talks about -- he still says that --

Right and they're still both locked into that. So basically -- and we spent days arguing. You know, we just sat there. On Monday, just sitting down, we're going to try and figure this out; resolve it; no. There was no logical way to solve the problem. He wanted to go his way. So all of the lands have been done that way in the government stuff, and all of the long haul stuff has been done the other way. The lands have been done with virtual circuits, basically because Vint and I split.

Oh that's interesting.

Now a days, I've been arguing that we should go back and offer

about the technology anymore. The cost of communications is cheap enough that we're not killing people with the overhead of a few extra bytes and the length of the packets have gone up because we have bigger things to communicate than just terminal communications. But and so I felt that although we do need circuits for voice and video and other things, and VC's are very attractive for _____ to keep a hold of the connection, we want to probably do something with packets over them, and I've been pushing that, but it hasn't gone too well in the ATM community yet. But there's still that split though, and we have to develop a technique for doing a two inlay emulation. It's sort of crossing over to do that. So people are building systems that put packets over ATM, which is basically a VC oriented technique. So that split occurred back then and has sort of propagated ever since. The Internet is right on that curve. I've gone through with the NS people and got the cost of all our equipment and all of the cost of Internet and the bids going through and it's basically right on the curve. And Wiltel's(?) price for ATM is almost on the curve and AT&T's prices are appropriately above it, but almost on it. So that we're basically, we're almost right on the curve with the commercial prices are coming out. The reason for that is basically Wiltel. Wiltel has priced things to try and price it near to lease line cost which is what that curve is, so that they can get the business. They don't have a switch service to worry about and so AT&T does and they would rather not do that, but Wiltel's forces it, so basically, you wind up with Wiltel dominating the pricing for emulating ATM, by pushing it down just by being there. And people are getting in it like _____. There's still a lot of commitment to that price compared to the Internet. In other words -- well Internet _____ gives a payment for your interface for a year, but Wiltel, you have to pay for your band with -- whatever it is and at that price, but if you figured it out if you can use it for my normal 75 hours a month, which is what any line is generally used in the network at peak rate, then you get on that curve. So things are coming out on the cost curve and that's what I've -- what that represents, which means that we'll continue to move along this curve. Now the other interesting thing on circuit switching is what we have here, because it crossed the circuit switches way up there. Of course, circuit switches is if you look at the investment in the telephone network today, you find that circuit

brought in a bunch of very young people.

And Wesler was young, yeah. These young, smart guys.

Well yeah, and it worked real well, because it was a new field and the older you were the harder it was to change your mind, so better to have young people. My philosophy -- heavily affected by what happened back then -- was that you've got to be able to change and if you're not, you're going to be left behind. And that applies to your personal life and relationships. It applies to technical life. It applies to virtually everything that goes on. If you're not open to change, if you're not open to accepting the fact that things are different than when you made up your mind, and looking at it and accepting the fact they're different, you're going to be in trouble. You're just going to not be able to deal with it. That's why people grieve over death for so long. They can't accept the change. They don't go through and reprogram their brain and rebuild it better. I'm convinced that the reason that they grieve over relationships being lost or death or anything else is because they don't know how to go in and restructure their minds to rebuild that foundation. And I've just decided I'm not going to allow that. I'll restructure my mind in a way that it isn't subject to that so much. I don't build so much on pillars. I have a flatter structure somehow that I sort of organize and anytime somebody challenges a piece down there, I say, "Okay, let me look at that piece and if I have to tear it apart, I'll tear it apart. If I've got to spend a day just sitting back and rethinking everything, fine, I'll do that." But I'm not willing to allow the same thing to happen to me as has happened to some of the people. I'm sure it will. It will be harder and harder as you get older, and that's what happens is it's harder and harder to rethink those things, so you become more and more resistant to change. That's probably because you don't have the right nutrients which _____. But the brain doesn't work as well. But until that happens, I'm going to be rethinking things all the time.

Have you always been this way -- open to change? Or is it something you've had to develop?

Well I probably was more or less, but when I really learned it is when I was putting these ideas out in '67. The fact that the world

During the period they were growing up, I was working on the Arpanet pretty heavily. Designing it and working at home.

And did they understand what you were up to?

Oh, somewhat, but not when they were real young. When Kenny got to graduate school -- I mean, to a college, not graduate -- he started learning about me, because he read things. "Oh, this is they guy who developed this or that." So he started realizing that I had done things through school.

Where did he go to school?

At RPI. Anyway, so back on the history. People started using it for all their computing very effectively, and as I said, I wrote that up from the network down quite well. And the resource sharing developed very smoothly over time. And some of the sites still became real resource centers where they wanted us. They only had four for big computing and other sites like that and ISI for PB-10 access or for general computing. A lot of the sites -- I forget all of them. SRI for the library -- that system -- and so on. So a lot of sites developed as resource centers that could serve a lot of sites to people doing things, and that certainly helped. We had a whole program to develop those people and those sites and those things. But the Arpanet still as an overall piece was only a fraction of the Arpa budget.

What fraction was it?

I don't know that I can remember exactly, but it probably was somewhere between a fifth and a tenth of the budget. We didn't actually have to invest that much in the network itself. You know, the development _____, the cost of the tips, so it was relatively small and the research programs were the bigger part. But independent of that, the saving in the computer side was greater than that. So the program probably actually benefitted us. But it sold well to Congress. It was easy to explain how that was going to affect the global communications for the military in the future. Reliable and effective communications, economic communications and everything else, and of course, that's been true. For the military, it's been very heavily used.

When you were talking to Congress about it, did you talk about the vulnerability aspect?

Oh, yeah, the reliability or vulnerability was clearly a factor we used with them to sell the program and one of the ones which was important for the deployment of systems like this. The military has always found that important, so they have redundant links that operate automatically and so on; and so does the commercial industry. Nobody would use a network like this if it didn't have some redundancy, so that feel it's more failure proof, so that you get the very high reliabilities.

And it has been surprisingly -- maybe not surprisingly, but you predicted very robust and very -- except I can think of only a couple of examples I've heard of so far, which was when the Harvard _____ started telling everyone to send these messages to Harvard. That was a famous incident.

There were a few early things where the software screwed up totally. But later on in history, we had one big failure at Telenet which was a result of the routing algorithms we had used in the Arpanet and they just didn't work at that scale, and that was that we had all of our traffic grown to where it really was filling 56(?) kilabit pipes across the country. So we had a pipe from Dallas into Washington and up to New York, and a pipe from Chicago through to New York and the East Coast. So we had two paths across the country; one through Dallas and one through Chicago; and all the traffic was perfectly balanced in these two paths. One day the routing algorithm which was supposed to decide how to route traffic -- the router in Chicago decided to route it all to Dallas because Dallas had a little less delay. Chicago path got a little congested. So he routed all the traffic to Dallas; not just a little bit. And the Dallas path then collapsed because it couldn't handle all of it. It would be 100 kilabits of traffic. So then the thing oscillated and the Chicago path would take back over and it would bounce right back and forth, and would do that -- just total collapse. And so we quickly went in and surgically fixed the routing algorithm so where we realized that with commercial networks with time as the volume builds up with a lot of low level traffic, statistically averaging, that you're going to build up very smooth, you know, mid-day period peaks that are very

predictable. That the traffic across the country is predictable within two percent any given day probably, because it's just a lot of -- statistically, it's _____, and so I could predict it month by month -- it's growing -- but, you know, very, very predictable; maybe within 10%, but very close. So I didn't need to have a routing algorithm. It was deciding the global stuff and that was done by designing the lines to be the right size and global long term decisions. The short term decision making that, you know, decided at this moment to route this here or there has to be done on a call basis at best. In other words, this call is going to take that path or that path rather than all the traffic for something like that. Well if you don't have calls, if you have datagrams, it's a little bit difficult. So you have to decide -- if you decide datagram by datagram, each datagram is going to make the same decision. They're all going to go south. So that was the problem we had. Cause we had really built the virtual circuit thing on top of the old datagram structure, and we couldn't change it quite that easily. So we had to go in and revise that some. But we just, you know, learned that the nature of large scale traffic is much more stable than one would have imagined when one's thinking about all of this random traffic. You know, people doing wild things and huge _____. I think the same is going to be true in ATM. People are mentioning that there are serious problems with the long haul networks and all the traffic variations. Because people will be sending 100 megabit things and big transactions. But what's going to happen is as the network goes through some intermediate period that will be a problem because the lines won't be that big compared to the users. But as we get a little further along, the volume of users grows. So we have hundreds or thousands of people using any given trunk, then that won't be a problem of very stable traffic. We can predict pretty well. And we can route it on a per call basis where there's capacity available and the algorithm have progressed a long time since then -- a long way. But the original concept that Paul Baran had given us, basically the hot potato thing, just fell apart back then in about '78-'79.

When was Telenet formed?

'73 we formed it and got our license. It was the first carrier actually after MCI. It was the first data file. There was another

It was good. Anyway, so I ran the office. I kept the number of people in the office very low and the high number of dollars per person so that I had very few people in the office actually. Virtually no one but me for a little while and then I added some people. Barry Wesler came to the office who's been working for me up until recently. And other people, and Bob Kahn eventually. But in any case, I found that by giving each person a lot of dollars in responsibility, -- you know, like $10 million worth of contracts to pursue -- then they would have the responsibility of, you know, a 100 people for them or something like that, which was reasonable management level. I mean, in other words, $10 million would buy 100 people out there somewhere, so they would have a big enough research area that they could -- I could get a senior person to do this. Now as if I did it like some of the other Army offices and so on, I'd wind up with a very small amount of money per person and then I'd get very low level people. So I kept it fairly high level. I'm not sure it stayed there, because I think they added more and more people every time. But for then it was great. And I started building up the Arpanet program along with all my other programs. Lick had prefunded a number of the programs like MIT by two or three years in advance, and so I used the fact that he had done that to take the $15 million budget and not refund those programs but do all new programs each of two years, and so I got it up to $50 million in a couple of years. Because the government -- Congress would say, "Well okay, if you're doing this and you're doing this in your budget, then we'll fund both of them next year, and then you're doing all three," and so on. And so by using up the compounded funding that he had put out in the future, I managed to multiply the program up to a much bigger program. And I got the ... program going and speech understanding program on a much bigger artificial intelligence program, and in the middle of all that time, the Mansfield Amendment came in and we had to really start being more careful about defending everything.

Now what was the Mansfield Amendment?

Basically it said that you had to have defense relevance to everything. Basically demanding that of all the programs. That if the defense department did it, that it better be for defense in some respects, and so we had to defend every program with respect to what it was going to do for defense. Which that wasn't too

hard. Almost everything in computing is going to benefit defense. i mean, as you saw in the Mid-East war, what Arpa did in computing and stuff ran the war. It was the whole thing.

What was the reason for the Mansfield Amendment?

Oh, Mansfield just got disgusted with people funding things in research and he wanted to tighten up the ropes. I mean, he thought people were funding ridiculous things. He's always had that view. I mean, he's always tried to cut down operations. Well it hurt the basic research fraction. We were able to keep a core basic research because we claimed it was important and critical. But we couldn't get the same size to it we had before, and I could do a lot of applied development programs. So the Arpa network, the ... and some of the other programs were good applied programs that had a clean goal and a clean thing and a big program that I could justify. So they were real good under that environment because I could clearly justify them well. And so those programs probably got more attention and more money than they would have under more liberal government because I would have perhaps put more into the basic research to keep it more that way. But as things progressed, it got harder and harder for MIT and other people to get the kind of funds for just a lab to exist without having specific things it was doing.

Well in any case, the Arpa network I worked through '67 and turned out a paper for the Hot Springs Conference in -- not Hot Springs. That was the other one. For the Gatlinburg Conference in Tennessee.

Right. People refer to this conference.

Right. That was a very unique and powerful conference. It was on operating systems principles actually, I guess, and Corbie gave a paper and so. But it was a very small group of people and very high level group of people and we all had great interaction.

Who was there?

Well from the UK, Donald Davies sent somebody. It wasn't actually Donald. It was one of his people from the National Physical

Laboratory. They had been working on packet switching. And I went from Arpa and Corbie and a whole bunch of other people went from other places. The interaction that occurred is I presented my paper on the Arpanet saying what I was going to do to build this network, and I'd been looking at the design and so on, and working out how to do the packet switching and so on.

Was this the first time you'd kind of gone public with it?

Right. It was the first public paper I wrote on packet switching, outside of the experiment that I did with Tom Merrill on the two computers we linked up. And the papers from National Physical Laboratory was presented. Their plan to do packet switching in a local environment for their local lab. And they, of course, claimed the word 'packet' because it was an English word. And so they presented the paper and I said packet's a good word. I'll use that. And I talked a lot with them and I learned and they convinced me to go ahead and up the speed of my lines. I was thinking about using slower speed lines like 5.6 and they suggested I go to 50 kilabits and have less lines but higher speed to get better response time. So that looked like it was reasonable.

The Brids convinced you of this?

Yeah. So I incorporated that. And they told me about Paul Baran.

They told you about him?

Yeah, because they had met with him and talked to him at some point. I didn't know about him at that point.

When I asked him about that, he said, "Yes. This is a very awkward question." Wanted me to ask you about --

His papers were actually around the office it turned out and Bob had collected his papers and they were on the shelf somewhere -- mostly in the safe, because they're all classified or a lot of them, but I had never seen him. And so I talked to Paul and I -- I mean, I talked to them and they said Paul had some work in routing and so why don't I look at his paper, so I did, and then I talked to Paul, and then we talked about it. Now from him I got

the routing algorithm that we started ... It wasn't very good but it was what we started with, and it was a way to start in that area. So Paul's work contributed that piece of it more or less in the routing area. The British work contributed probably the speed and the name and I sort of contributed the topology and the design that I had done. So we each contributed our piece of it and then I went ahead and did it. As far as I can detect, the three research activities were originally independent from 1962 to 1967.

Well that's the fascinating thing about inventions and discoveries is that when everything's in place for the technology to --

Yeah, Paul was clearly the first version published, because his papers were published in early '64 or so. But I just sort of like my paper with Tom Merrill. But mine wasn't the design of a network. It was more to see what the problem was. And he was actually publishing about his thing, but of course, his was aimed at voice and was aimed at essentially a secure voice system and it was not what I was looking for at the time. I mean, I couldn't -- an that's why I probably didn't look at the papers was because a secure voice system wasn't particularly interesting. And it was classified too in large part. Some of it was classified. Some wasn't. So it was very hard to work with and not many people had seen it. So he had actually had some public publications before that time that were in the press somewhere. I never found them actually. But I've heard they were existing. But mostly it was the set of reports from Rand that had been done, and of course, it was all Rand people and wasn't just Paul. A whole group of people there had done the work. But there was really no interaction between me and either of them until that point. The interaction occurred between Donald Davies and Paul somewhat earlier. A couple of years earlier they had met and talked. And Donald actually met me at MIT at a conference a couple of years earlier and talked to me, but we didn't actually talk about this and I didn't get anything out of it. I mean, we just happened to be at the same meeting, we've determined by retrospect, but that's about it. ... So it wasn't an interaction that I can detect at all or certainly any influence until that meeting. Then I picked up everything I could from both of them. So that appears to be as best I can trace the invention source was sort of in triplicate. However, Paul generally gets the credit for having invented it because he

published first, which is reasonable.

Yeah, and he even claims there was a year lag from the time he finished the work to the time Rand got around to publishing it. He was actually done a year or two earlier than that.

Yeah.

The first thing he said to me was, "Have you read the papers?" when I met him yesterday. I said, "No, I don't have them. I'd like to read them. I don't know if I'd understand them. But certainly for doing this book it would be very interesting to read them."

I don't know whether you could find them even this day and age.

Well that's right. All he had was a couple of bound volumes that someone had bound for him. He couldn't find them other than these.

I think that one would conclude they wouldn't be terribly useful. They might be interesting but they are very oriented to the secure voice system over T-1 carriers.

Well and he to this day -- what came out of the conversation with him was that to this day he's concerned about enemy attack. It's an interesting perspective, because your approach as I understand was really resource sharing and his was vulnerability. And he carries that through to today. He went on for quite some time about it.

What he argued was the historical basis, and what difference is there between what I've said and what he said?

He was actually a bit in the dark. He wanted me to ask you when you knew about his work and I think it's a source of some -- I don't know what the right word would be -- sort of frustration for him perhaps. I don't know.

The only interaction was the fact that I read his papers and talked to him and got what I could out of the writing from him. But his work had stopped and there wasn't anything else to do.

Right, and he said that. And he said he went onto other things.

Right. So he was never involved with the Arpanet per se. Nor was the Physical Laboratory. They were probably closer. They kept in touch and we kept them in touch, and I tried to get them involved and later on in time they did get involved in the Arpanet. But they were very anxious for an experiment to happen because they hadn't been able to get funding. So that they're problem was knew what they wanted to do. They never had any funding and I was able to produce the funding. So I was able to therefore do the first network that was ever built and that was because the government had the money. So that's why I've gotten most of the credit is cause I did it, as opposed to talked about it. Also, it is probably historically equal with the three of us as far as I can tell as far as the source of the thing. It wasn't too hard in those days if you were a computer person to be thinking this way. Because what would you do? You'd send blocks of data. You wouldn't set up a channel like a voice person. In fact, I tried that in an experiment with two computers and it was useless. That was clearly not the way to operate.

You mean even though it worked?

It was so uneffective in terms of delay and everything else that you needed some better mechanism than that to do it. I mean making the calls through the switch telephone network was not the way to do it. Because you needed responsive mili-seconds, not seconds to do things. So my conclusion was, even before I did the experiment, it was the only thing I could do, was that there wasn't going to be a right way to do it, but I wanted to prove it and get the right results, and see that I could make the computers work. But I think anybody starting out in communications at that point, even if you went back to Lick Lighter's old papers on the global network, you'd probably see something about the fact that it ought to be done with computers rather than something else. But I don't -- I couldn't ever find anything. Those papers hardly exist and I don't think anybody's gone back to check with Lick Lighter of whether he has a record or file of anything old. But I mean, he was the first person probably in the government funding things and so on back in the early 60's to write about the fact that he thought this research here was important and somebody ought to do something

about it and it ought to be somewhat of a 'galactic network', he called it.

Yeah, Taylor attributes a lot to Lick Lighter in terms of the conceptual basis.

Well he carried through a lot of Lick's thoughts, I think, and talked about them. But Bob was never the technical person in the office. He was a manager and so he didn't really have a way to implement anything in terms of these thoughts, so he picked -- he was very good at getting people like me or the people at Park, and so when he went to Park, he picked all of those people and got them to do things. And so he was very good at getting people to do things. He wasn't the technical person himself. So he's probably best viewed as a tremendous manager and people person to make things happen.

Yeah, that's what I've heard about him. Well, I've met him before actually too.

Back then he was a great woman's person ...

Yeah, I've heard that too. We won't get into that. Now what about the process of coming up with the RFP?

Well the RFP was written shortly after this conference in '67.

Gatlinburg?

Gatlinburg. I finished the conference. I published the paper there and got my feedback. Did some more reading and research and did the RFP in '68 and got out and got bids and got the award settled in '68 -- late '68 or early '69 -- and then BBN was the one we chose. We can go through that if you want. And they then worked through '69 and built the switch. Actually, by the end of the year we got it installed.

Right, nine months. These BBN guys didn't know anything about any of that -- any of the process by which you came up with the RFP. The other who did -- was the RFP classified?

No. ... RFP for people to do both select a computer, some sort of mini computer, and do the software to do an implementation which we strictly defined. We said we wanted exactly these functions and exactly this technique.

It was very detailed.

And so I wrote that saying exactly what I wanted to have built so that we could connect the computers together and it would have a certain kind of host interface to connect with. The computer committee working on that to figure out what the host interface should work like and all the, you know, technical group of people which -- Steve Crocker worked on the host protocol in that area. I'm not positive who was the primary person on the interface, but Steve was the primary person on the protocol.

I think Kahn wrote -- this is the 1822 -- the host to implement this.

Yeah.

He told me he ended up writing that.

He well could have because we tried to work with a group to figure out how, but BBN was the one who had to implement it. So probably he did it there, and he wound up doing some of the other key things in terms of the actual implementation of the algorithms that I specified. I mean, I said, "It should do really this way," and so on, but he then had to figure out exactly how to do that and so on -- or some other people there did. I don't know. Other people. Severo Ornstein probably did a bunch of the key things too. He was one of the brightest people there. So that all happened there. I mean, Bob got pushed out of BBN really because Frank couldn't stand anybody that bright.

Frank Hart?

Yeah.

Yeah, I wanted to ask you about your perceptions of Frank and that whole -- there was an uneasy dynamic between them.

Well let me talk about the selection for a second. The selection -- we got back responses from a whole bunch of companies. IBM and CDC said, "No bid because this is impossible. You can't. There's no computer small enough. It's going to be much too expensive to do what you're saying. No computer's that cheap." IBM was thinking of a Model 50.

What's a Model 50?

Well back in that time it was the 360 Model 60. It was a great big machine. It filled a room. To do what we were thinking of as a mini computer. But people had mini computers then. It was the first year of mini computers. And so everybody, who was essentially a software group like BBN, just went out and selected a mini computer, and the machine they selected was selected by probably 60% of the people. It was a very common choice.

The Honeywell?

Yeah, the 316. And so we got the proposal from Rathion. It was the second best proposal and there was a bunch of others.

Do you remember much about the Rathion proposal?

Yeah, it was a good team by -- the name of the lead guy escapes me, but I've seen him recently. But Rathion had a much more deep structure so that the hierarchy went down about five levels for the team they were proposing to do this. And my belief was after interviewing Frank and the other group and looking at their things, Frank had a very flat structure. I mean, everybody reported to Frank, basically, and Frank was the den mother. I mean, really, he acted sort of their father figure and, I think, ... father figure like Bob Kahn, they had to leave. And he was essentially a dictator. He handed out the task and he handled all the things and he operates that way and he operates very well that way. And as long as you work for him, it works very well. Some people can't work for him because it's totally infuriating. But to the extent you can then -- but what I saw at that time with the selection was that he had a pretty flat team. So I didn't have this hierarchy of managers to go through and I thought it was going to operate a lot smoother and we would have a lot better progress and they had

pretty good -- they didn't stick just to the RFP. They went off in some areas where they thought they could do something and they proposed it. So it looked like they had some good ideas. So did Rathion in various areas, but generally, technically, I think they both came out about the same. It was mainly a decision on the team that we would go with BBN. Which, of course, made a huge difference in BBN history.

Oh, absolutely. They're still milking it.

They've lost a little bit of that edge sort of lately. But in any case, they had that and so I worked with them and I came to know Frank, and Frank was basically, as I say, I call a dictator, which is a benevolent term almost. I mean, he basically ran the team by essentially nobody being able to do anything unless he knew about it and then gave them the task and they followed up with it. Which made sure that everybody was closely coordinated and he knew what everybody was doing and so on. It made it impossible for people with brilliance to function very long, and so Bob Kahn just couldn't stand it. And I understood that. It was no problem and so I brought Bob to Arpa because it was a better place for him, and Frank was basically very capable of making this happen. Happen on time and on schedule and work fast and so on. So it was an interesting thing. I mean, I wouldn't have wanted to work for Frank, but I thought as a team it worked very well for me.

[Tape 1, Side A ends.]
[Tape 1, Side B begins.]

You want someone who can really build and do it in nine months or whatever your time frame was if you'd had a time frame. I don't even know if you did. Frank Heart's your guy. Did that happen?

Well if it did, it wouldn't have been appropriate within the RFP process to consider it other than in the process. But as I say, the process was that we get all this team evaluation of the thing, and under standard government process, we had teams that evaluated the technical and every other characteristic that rose with the cost and so on, and then we came down to a final decision between the two, and that was decided based on the team. And so maybe if that input had been given to me, I don't know. I clearly knew the

team and that Frank was leading the team and what it was like.

What was the first time you met him? The day he came to Washington to talk to you?

Yeah, about that time. I don't think I had met him before this.

Do you remember what your impression of him was?

I thought he was going to be a good team leader. I had no qualms about him doing the project. Later on, I learned more what his structure was like, but even so, it worked well for what we were doing.

Right, sure did. Did you have the nine month requirement?

I don't know whether the RFP said what it wanted it in, but surely the shortest time possible was the best thing. So I was very worried about it taking too long, that's why I didn't want to go with a group that had too much structure.

Why were you worried about it taking too much time?

Well because to keep the momentum and the activity going, it was best to move fast to get the thing done, now that we knew what we wanted to do and had the money allocated. If it had taken two years, I wouldn't have gotten the next round going. I mean, it would have delayed the whole program. Not that it would have changed the face of history a lot, but it was important to move ahead. Because we couldn't do anything else while they were doing that.

What do you mean you couldn't do anything else?

We had to do the host protocol and that sort of thing, where we couldn't move on doing experiments. We couldn't develop network technology without --

Right. You needed it in place.

Right. We needed something in place to test. And once we got the

funding and the plan and everything else set up, it was important to proceed as fast as we could. It was valuable to. I mean, not critical.

Did BBN have a reputation that you were aware of at the time? A lot of guys had gone from Lincoln. In fact, Frank and Crowther and Walden.

Well it certainly had a reputation for a lot of people like that. I mean, in fact, Lic Lighter had been there for a while. So I knew that it had a lot of research folks from the Cambridge community. I've done a lot of -- you know, I spent a lot of time back then working with various projects with BBN, so I don't know how involved I was or whether before that date or whether it was after that date. It would be hard to reconstruct.

So though small and though pioneers basically in acoustics, this was not --

Yeah, I mean, the fact that they won this bid was because they made a good proposal and had a good team, not because of their company's reputation.

I thought I'd try to go back and find the original RFP and the bids themselves were probably -- I just wanted to find out --

The bids themselves, I don't think you'd ever find, because that was strictly --

Do you remember who the other bidders were? How many there were?

There were probably 20 more or less. I don't know exactly who they were anymore. I'm not sure that there's anyway to find all of that, even RFP. I mean, BBN might have a copy. The government might have a copy. I doubt that the government could find it. I might have one in my basement if I searched.

Who wants to do that.

I don't think -- I mean, I do have a lot of archival documents that are in some boxes. If you get desperate for documents, we could

look through my storage shed.

Well it's the nature of the book and book writers to look for anything. Any archival information is gold to us.

Well that's what it's there for. Someday somebody might want it. I don't know. We can look if you want someday.

What was the reason for choosing the original four sites and was that a part of the RFP? Did you know about it at the time?

I'm not sure it was part of the RFP. It probably wasn't, because it wasn't important to the RFP. What was important was that we build the switch and we start installing it or we set up four locations. We may have set it up beforehand. What I did was I had about one or two dozen research sites that we knew had computers, and I wanted to start sharing their resources. None of them wanted to. So people like McCarthy and Minsky said, "No way. I want my own machine and nobody better take another cycle from it for anybody else." And I told them, well, their funding depended on them cooperating and so they finally cooperated, and then eventually, they decided it was a great thing. But to begin with, most of the sites were pretty uncooperative. The four sites that were most cooperative were probably the four we chose. And UCLA clearly wanted to be involved in the measurement activity and it was important to get them involved right away from a measurement point of view.

Was this because of Cline Rock(?) and he was there and he was into this kind of --

Right. And I knew Cline Rock. We went to grad school together and he was the best one in that kind of technology. You know, _____ _____ and still is. So it was clear, you know, that he knew what he was doing and that we could in fact count on him to develop a theoretical model, check it out with the actual, and correlate the two and have a true understanding of what was happening, starting to develop. We had also the people at SRI where I think that they were involved in the first one. They were all excited to put their resources on line -- Bart's group. And the Utah was probably not as important to be on, but was cooperative and

supportive and had a group there that was not too far away physically from the others.

And was Sutherland still there at Utah at the time?

Yeah, he was still there, I think.

Was Wesley there at the time or had he then went back to Utah?

He probably was back there later on. He was with me during the time we did the RFP and then left to do his PhD later. The fourth site -- I forget -- where was it?

Santa Barbara.

Santa Barbara, yeah. That was not that critical either. But Ben Color(?) had a good research program and it was at a good location. They could do it -- set it up. Basically, they were cooperative places outside of UCLA. We had this whole network laid out that we wanted to do and this was just we wanted to start without too much communication lines and in a place where we could get around and handle the logistics of installing it and getting it up. And so that was a convenient starting section of network and then we grew it from there fairly rapidly as you've seen on the charts. And then in '71, put in the chip, which was the first terminal access control.

Now, Webster was saying that he came up with this _____. Was that -- no?

I don't know. He could have. I mean, I have no idea about who came up with the idea for the chip. I mean, we knew that we needed terminal access. Somewhere along the line he may have put forth or pushed the idea or something. But somewhere along the line we contracted with BBN to build that version. So he could have had that idea. I don't know. It was sort of a natural evolution of what we wanted to do because we needed to try and get the computers connected first, but then we really did want to connect terminals outside of them as well, without having to go through them. So we essentially built a pseudo computer to have the inputs. And once we knew what the protocol worked like and how the Telenet and FTP

and all those things worked, generally, -- we hadn't finished the protocols and finalized them -- then we knew how to go ahead and build the Telenet type interface protocol ...

Were Telenet and FTP in the RFP?

No, we developed all that separately. See, the FTP was one piece of the program -- BBN's program -- and then I had simultaneously a group working on the host protocol and all the sites working to try and prepare their site and work together to get this stuff done. And I had a number of parallel programs to try and get other things ongoing. One of them was to develop all of the protocols and FTP and Telenet and so on were some of those. And sites like BBN's PTP-6 and, you know, other sites, Harvard and so on, did a lot to work on some of these protocol developments, you know, and get these things going. And electronic mail started happening as just transfers of blocks of data, you know, and just a transfer. One person on one machine would want to send a message to someone at another, so they essentially send -- they type in a block of data text and then they send it over a _____ or Telenet, whatever, to the other person.

Oh, I see, so they would use an FTP or whatever to send.

Yeah, they would just use the transfer, and then what happened was that that started happening a lot and I started getting messages that way on my machine at Arpa.

What started happening a lot?

People would move the messages a lot. Now then you'd turn on your _____ teletype and you'd print out this long stream of stuff and that was the only way you could read it. So I got tired of that, because I was in an Arpa office and I had to read all this stuff from all these people. So I went in and built a program out of Teco(?) macros to sort all the messages into a list to present me a list of all the messages when it came up and to be able to forward or copy or, you know, to delete or search and read just the one I want, and delete them and so on from the list. And that turned out to be the start of the first E-mail program. It was the first E-mail program to read it, because otherwise it was almost

impossible to deal with.

So you came up with a sorting mechanism.

Well to put the thing on the screen so I could have a list of messages, and I could read any one I wanted. I could leave them. I could forward them.

Did they have a subject _____?

The information and the structure of the header or the message was already developed in this process of developing the protocols. We had decided on a header format. That there would be a source and a destination and subject. So I knew where those fields were. I just had to sort through the text, find it, put it up on the screen. And so with Teco macros I searched for the right separators and found the fields and threw them up and so on. When they saw that, they decided to write their own programs and we've got thousands of them now in existence which do electronic mail, you know, _____. Almost looks identical to what I had originally. Nothing's changed. Same functions basically.

And did you then proliferate that over the net?

No, I just did it and people copied that. It was Teco macros, so it was easy to copy on the PD-6's and then people did their own real programs after that. I mean, I didn't have time to program something from scratch, but I did it with Text Editor Macros. It allowed me to do it effectively and hide it all, so nobody saw that it existed. And that was fine. It was fast enough for anything I had, and then people wrote real programs to do it later on in time as they saw that that was convenient. So that propagated a little bit and then people wrote their own.

And also, I should think it seemed sort of incidental to you that the importance of the future is what was essentially a way for you to make things more convenient for you. Wasn't that you were out to --

I wasn't trying to _____. I was just trying to make it more convenient for me. E-mail became very important in Arpa.

LARRY ROBERTS

He and my mother both got their PhD's at Yale in chemistry.

That's where they met?

Yeah, and then he worked at ~~Gar~~ Dover Oliver which was a large fluids solid company in Connecticut.

What was it called?

~~Gar~~ Oliver, D-o-o-r. Anyway, he was the head of the research and development and he had a whole slew of patents and developments in terms of fluid solid separation, gold separation, and all sorts of techniques for that. In addition, he actually developed a lot of amino acids somewhere in his early history, but I don't have a ~~lot~~ of records of that anymore. Any case, he was in ~~country(?)~~ chemistry and I decided that was too common or known, where the frontiers weren't ... enough, and so I wanted to go in something where things were changing much more fast and rapidly, so I went into electronics, and decided that probably in junior ~~hi~~ high school.

Where was this?

In Connecticut. I was brought up in Westport. And so I started working on electronics and, you know, building radios and TV's and other things, ham radios, and devices of various kinds, and then went to MIT.

Was that a given? Were you pretty sure you'd go to MIT?

No, I didn't know where I was going to go. When I started applying, I applied at Harvard, Yale, MIT, and somewhere else, and got accepted everywhere and I still had to make up my mind. But it just seemed better for what I wanted to do. Now when I got through with undergraduate, then I found that it would have been nice if I'd gone somewhere else on a graduate, because now the graduate was the best place to go for computers, but that was fine, and I went on there and worked at MIT, Lincoln Lab, for a number of years. Was working there actually when I got my PhD. Well you don't want to go way back into this.

Oh, yeah, I do.

Oh, really? Well at MIT, I started into computing in about '58, I would say. I was going to graduate -- undergraduate in '59. And around '58, I started working in the computer lab and I designed some equipment for them, and then I got involved with the ~~TXR(?)~~, which is the first computer that MIT had built -- that Lincoln had built -- a transistor computer, and it was the first little one. it was the -- PDP-1 was the follow on that ~~Deck(?)~~ built. It was the same machine basically.

Olsen left MIT and as a spin-off --

Olsen built the TX-0 at Lincoln and then went to ~~Deck~~ and built a PDP one which was a copy of it.

Was it really a replica?

Oh, pretty much. I mean, he changed some things, but it was pretty much the same thing. Lincoln didn't have any problem with that. It was not an issue. It was just a question of he did the best he could to improve it, but they ..., but he didn't change it a lot. Then he built the PDP-6 which is almost a copy of TX-2 which is the actual machine I work on, except it was more memory and other things that we didn't have then. But the TX-2 was -- Lincoln built two machines, the TX-0 and the TX-2, the first two transistor machines there. And the TX-0 went to MIT campus in '58 and I spent that year at MIT, my senior year basically, I spent 700 hours on the machine and I don't think anybody, at that point and time, had spent 700 hours running a machine, because they were -- IBM machines, you got five minutes on, you know, and so I managed to get a lot of time on it because it was the first sort of machine available for individuals to play with. So I did a lot of research on that.

What was the nature of research?

The first research project I did was to do pattern recognition, handwritten character recognition, and it was with ~~Neuronet~~, which now are becoming popular, but were then popular a little bit, and there was a lot of talk about them, and so I wanted to investigate

whether they were worthwhile working with or not. And we had a very strong artificial intelligence group at MIT with Minskie and McCarthy, and they thought that this was nonsense, and the guy who was pushing it, Rosenblat, was a charlatan pretty much as far as we could all tell, and it was. But he in fact -- but the technique worked more or less. But he pushed it. I mean, his publicity went way beyond what it was. So I did a serious study of how much you could accomplish with it and got good handwritten character recognition on the computer and published that back then. That was my first published paper.

What was your dissertation on?

Well then I did my master's dissertation on ~~bend...~~ reduction using pseudo ram... which was TV encoding -- well actually, facsimile images, but essentially it was used for TV throughout history, and that was how to compress bent images through pseudo random encoding. In other words, not have fixed clip levels of intensity but pseudo randomly moving ones. That the other end would pseudo randomly move as well in sync so that you could in fact not lose any information, but you gain the advantage that the picture would not have clip level boundaries in it. If you clip pictures at like eight levels, you see a lot of boundaries in the pictures and that's very bad. But if you do those -- if you vary the levels dynamically with time, pseudo randomly, then you can't see it. It just looks like noise. The eye washes it. And so it's a much better picture. MIT and I patented that and it was used for all the moon shots and Mars missions, but it was government free license, and it wasn't until 20 years later that it was used in facsimile and that was after the patent ran out. So it was much too early.

Oh, really? What is the time on patents?

17 years. So when I went to Japan many, many years later and talked to various people about facsimile, they said, "Oh, yeah, we ended up using pseudo random -- whatever." I said, "Oh, let me see. Gee, my technique."

You can't renew patents?

No. It's intended that -- I mean, like Xerox would have loved to renew their patent, but it's intended that people be able to compete eventually. Anyway, then I went into my PhD thesis which was machine ~~presumption on~~ three dimensional solids, which was taking photographs, reading them into the computer, processing them to determine what the orientation and the structure of the three dimensional picture was. So I'd look at a picture of a table and I decide, well, this must be cylinder at this angle in order for me to see what I see of the two dimensional view of it. And I then conclude that it was supported by this other cylinder underneath and I presumed -- there was weird theories at that point and time by ~~against~~ Dait(?) and other people about how you saw in three dimensions. I mean, really weird. People had wild ideas of how you did it. What I did was I took a few assumptions that we base all of our decisions, because not on stereo and not on texture, which was a big deal then and other things, but basically on support. That is we assume gravity and that we know the models of things. We know that this cylinders and squares and rectangles and other things and people and other things we know about. We have those models in our head. We've learned them, and then we just use those to figure out where they are in three space. And it's all easy to do once you do that. And so I proved that it was doable and the computer could easily duplicate it. Now if those were the theories and you use them, then you could in fact figure out from any photograph where the things were in space, and then I displayed it from any point of view, so you could prove that it was there, and that was the part of the thesis that was used the most. Because 3-D display with hidden line elimination, that was the first time it had ever been done. And to do that I went to four dimensional geometry which is homogenous coordinate system which is a paper which was never published in anything very significant outside of my thesis and has gotten everywhere and is the basis of all 3-D display today. Because what I did was there was no math for projective geometry and modern day science at that point and time, because computers had never used it and nobody cared otherwise. So the only projective geometry was around some German books that showed you how to do it with compasses and straight lines and it showed you what the mechanism was, but it was mathematically awful, and I then combined that with Matrix theory, which had never used it, and so I developed the four dimensional matrix that would then do a prospective transformation of anything,

and that's been the basis of all 3-D display since then. And my other -- the paper on this has also done similar work on all of the hidden line elimination work. And for many years, people kept on beating my work and doing better in terms of being able to do it faster and faster, and then over time as the resolution of the displays went up, it came back to the technique I used was the best technique, because I had done it in infinite resolution and not depended on the resolution of the display. I had taken an intersection of all the surfaces and computed them, instead of just looking at projecting each point in the display back. After that, people simplified it that way, and then now they've gone back to -- some of them -- to a technique more like mine, where it's now the fastest technique for very high resolution displays. But that was a big thing for the next 20 years of who had the fastest program that could beat the next one before it. Anyway, my early work was on graphics and I did a three dimensional wand that you could find everything in three space.

Like a joy stick?

Yeah, like a wand or joy stick, so you could just move it in space. And it was actually a microphone and I had four transmitters that transmitted ultrasonic beeps and it picked up the four and it had a wire in it and the computer could figure out where it was in three space. And I used that to draw in three space and then move things, latch onto them, and move and all of that. All of the things that we do with a light pen. And then we attached a couple of those to a head piece and made a virtual reality system with two displays.

What year was this?

Well this was in -- Ivan and I worked on that together -- Sutherland -- and we did that in '65 probably. Somewhere in the '65 vicinity. And that was the first virtual reality system although nobody ever realized it. The literature doesn't go back and think about it. And you could move your head and see the display moving in three space. We only had wire figures then. We didn't have shaded figures. You know, we didn't have the computer power to do much more. And the computer was so pitiful compared to what we have today. Had 64K bites of memory ...

Like the first Mac.

Yeah, just terribly small amount of memory. And it had a six microsecond cycle time, so it was one-sixth of the ... Today's machines are 25 or 50. Just on my desk here. So the machines that we had -- the PC's that we had, as soon as we had PC's, were far greater than the original machine. But we did a lot with it. I wrote all the operating systems for the [illegible]-2, the compilers, and the real time operating system or the time sharing system. And then I sort of got tired of all of this and decided that -- well it's sort of a two-stage story with Bob's thing. I wasn't really tired of it. I was having fun doing all the R&D and so on, but in the background --

Were you still at Lincoln?

Yeah, it was Lincoln. And I always started the communications ... In '62, I made a decision that the -- finished my Phd in '63 -- but in '62, I went to a meeting in Hot Springs, Virginia with all of -- it was a conference and Harvey was there and Lick Lighter was there. A whole bunch of people from MIT and everywhere else. And they're all sitting around talking after the various sessions about what the future was and where we're going, and we'd all built these time track systems already. I built one at Lincoln and Harvey had built one at MIT, and we had time share computers with individual access and all sorts of computing capabilities much like we have today, in a lot of respects, except they were not individual machines so much. But so the real question was where do we go from here?

Was that an informal discussion?

Totally informal. We were off line at the end of the -- sitting around and talking. And Lick Lighter had always been talking for the last couple of years before that about this global network concept of networking machines together.

Did you already know him?

Oh, yeah. I knew him through MIT for quite a while, and so he -- he had been talking about this network concept and he talked more

about that. And we all talked, Corvie(?) and I and Lick and a number of other people. I can't remember all of them. And what I got out of the conversation was a conclusion in my own mind that I wanted to go into networking because I saw a future there that was -- that one person could achieve a tremendous amount of progress and achievement because it was a net field that nobody had ever pursued and it was going to be exciting and important. Whereas, in computing, it would take teams of people and it would be much harder to achieve the same results. So I sort of made a decision to start investigating and pursuing; applying computing to communication and how to do that for computer networks and computing.

So just after this 1962 meeting?

Yeah. So I started looking at how to do that and looked at and thought about the concept of package switching as a result, built an experiment which was a paper that I wrote with Merrill between the TX-2 and the SDC computer to link them together to see if we could have two time sharing programs call on each other for resources or communication so I could get a program run there that they had there ... and so on, back and forth. And that worked fine. We got a communication link set up with a Western Union 2400-watt line, dial up line, and it was -- it worked. It was particularly poor results in terms of the speed and everything else -- reliability and so on. But the computers worked fine and they could easily call on resources and ... the machine and everything else. So what I concluded was that the communication system was the pits and the computers were able to do this and communicate and have networks, and so the question was how do we fix the communication system? And the communication system was much too slow to go through the dial up system and much too slow and much too unreliable in terms of one link and so on. So I looked at how do we build better communication system and looked at package switching and started designing a system. That work was done actually for Arpa because I got an Arpa contract to do -- Ivan was at Arpa at that point.

And where were you?

I was at MIT and Lincoln Labs. And so Ivan was there and I started

this experiment amongst other things working for Arpa. And so Ivan knew that I had been working on this and had this interest, and he had Bob working with him. So he and Bob decided that I was the right person to take over the office so I could do a communication program and get something going in the government inside the Arpa program, amongst the other computing things.

What other computing things was Arpa doing then?

There was a whole base research at MIT and Carnegie and all the places like that. Lincoln set up big programs of basic research at each of the places to do the time sharing, the multex(?) and all these things. And he had an artificial intelligence program with Minskie, McCarthy, and those people. And pretty much, you know, SDC, and Rand, and all these places, you know, sort of the base research program was the biggest thing he had going.

Did there have to be for these programs some kind of defense application?

At that point and time, it wasn't a big deal. There was clearly a need in defense, and Lick Lighter wrote they were supporting papers appropriately to say how defense was going to need all of this. ... improvements in the field are going to make huge differences to the defense. It wasn't until the Mansfield Amendment that we got into serious issues of having to defend everything on that basis. I'll come to that much later. But there was a defense purpose always for the IPT office at Arpa, in the sense that it was a major part of defense to have computing capabilities and that we'd need it, and also for communications. So I told Ivan and Bob that I wouldn't come because I was having fun doing R&D and why would I want to go to Arpa and manage things? And I did -- I put them off for a long time. Bob probably knows how long in his mind, but I was having fun doing my stuff. But in the back of my mind I was seeing that what was going on was that we were doing all this research which I knew was never going to be used in the near term because we were so far ahead of where people were. The graphics research, a lot of it like the virtual reality hasn't even come into its own until now. The wand -- the mice and things like that have just become popular in the last five years. And all the graphics is just blossoming now as opposed to then. So when we had

a 30 year review of graphics a couple of years ago, you know, all this early work had done almost everything people were doing now and then it stopped because nobody could, you know -- there wasn't any money really commercially to make it go any further. So it was way beyond -- I mean, it wasn't anything done commercially. It was all -- if I got it done in software on the Lincoln machine, it couldn't be exported anywhere. So it was certainly useless to anybody else. All I could do was publish papers. So I was sort of disappointed. I really liked the commercial field having it get out there and do something. So I wanted more of that. And I didn't know exactly how to achieve more breadth to what I was doing.

Well anyway, so they tried to get me to come to Arpa because they wanted the communication program and everything else started. I knew artificial intelligence and I knew, you know, the time sharing, all these things and those were the programs they had. So they wanted to get me down there. So they talked to Hertzfeld. Bob can tell you this part better. They talked to Hertzfeld and said they wanted me. Hertzfeld said, "That's no problem. We fund 51% of Lincoln Lab. I'll talk to the director." So he called up the director of Lincoln who I forget his name and said, "You know, we're funding 51% of the lab and, you know, we think that you ought to get Roberts down here to take this job or there is going to be some impact on your programs."

Meaning we're going to cut off funding if you don't bring this guy down here?

Something along those lines. It was exactly specific, but it was just, you know, a vague threat that they better do this. So the guy -- the head of the Lab called me and said, "I think you better go to Arpa and we'll support you. We'll pay for your way. We'll pay for you down there until the paperwork happens. We'll pay for everything. You know, and you'll have a job here if it doesn't work out or whatever." So and then he counseled me on the fact, you know, that it would be good to get into management and other things like this.

What was your reaction?